

## **Active Debris Removal – a Grand Engineering Challenge for the Twenty-First Century**

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The collision between Iridium 33 and Cosmos 2251 in 2009 underlined the potential of an ongoing collision cascade effect (the “Kessler Syndrome”) in the near-Earth orbital debris environment. A 2006 NASA analysis of the instability of the debris population in the low Earth orbit (LEO, the region below 2000 km altitude) shows that the environment has reached a point where the debris population will continue to increase in the next 200 years, even without any future launches. The increase is driven by fragments generated via collisions among existing objects in LEO. In reality, the situation will be worse than this prediction because satellite launches will continue and unexpected major breakups may continue to occur. Mitigation measures commonly adopted by the international space community (such as the 25-year rule) will help, but will be insufficient to stop the population growth. To better preserve the near-Earth space environment for future generations, active debris removal (ADR) should be considered.

The idea of active debris removal is not new. However, due to the monumental technical, resource, operational, legal, and political challenges associated with removing objects from orbit, it has not yet been widely considered feasible. The recent major breakup events and the environment modeling efforts have certainly reignited the interest in using active debris removal to remediate the environment. This trend is further highlighted by the National Space Policy of the United States of America, released by the White House in June 2010, where the President explicitly directs NASA and the Department of Defense to “pursue research and development of technology and techniques..., to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment.”

A 2009 modeling study by the NASA Orbital Debris Program Office has shown that, in order to maintain the LEO debris population at a constant level for the next 200 years, an active debris removal of about five objects per year is needed. The targets identified for removal are those with the highest mass and collision probability products. Analyses from the study indicate that the majority of those objects are spent upper stages with masses ranging from 1 to more than 8 metric tons, residing in several altitude regions and concentrated in about 10 inclination bands. To remove five of those objects per year in a cost-effective manner truly represents a grand challenge in engineering and technology development.

An end-to-end debris removal operation includes, in general terms, launches, orbit rendezvous, precision tracking, stabilization (of the tumbling motion), capture, and deorbit of the targets. An ADR system designed to remove a single object is not very cost-effective. Therefore, the repeatability of the removal system is almost a requirement. Some of the technologies involved in the ADR process do exist, but the difficulty is to make them more cost effective. Other technologies, such as ways to stabilize a massive tumbling upper stage and the capture mechanisms, are new and will require major innovative research and development efforts. This paper summarizes an updated assessment of the environment, including what needs to be done to control the population growth, and outlines the major engineering and technology challenges to carry out active debris removal to preserve the environment.